

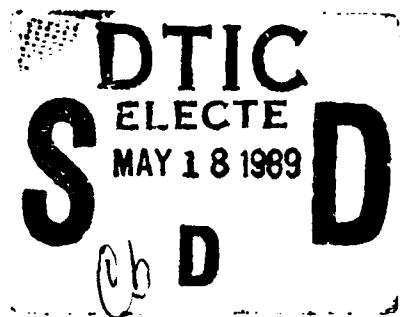
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Research Product 88-33

Implementing Embedded Training (ET): Volume 6 of 10: Integrating ET With the Prime System



December 1988

Manned Systems Group
Systems Research Laboratory

U.S. Army Research Institute for the Behavioral and Social Sciences

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Research Product 88-33

**Implementing Embedded Training (ET):
Volume 6 of 10:
Integrating ET With the Prime System**

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December 1988

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FOREWORD

This document is Volume 6 in a series produced by the Army Research Institute for the Behavioral and Social Sciences (ARI) and the Project Manager for Training Devices (PM TRADE). The series consists of 10 related documents for combat and training systems developers, including Army Materiel Command (AMC) laboratories and other entities, Army acquisition personnel, Training and Doctrine Command (TRADOC) Combat Developers and Training Developers, and contractor organizations involved in system development or development in technological areas under independent research and development (IR&D) programs.

The series of documents includes guidelines and procedures that support the effective consideration, definition, development, and integration of embedded training (ET) capabilities for existing and developing systems. The 10 documents share the general title of Implementing Embedded Training (ET), with specific, descriptive subtitles for each document. They are as follows:

1. Volume 1: Overview presents an overall view of the guidance documents and their contents, purposes, and applications, including a discussion of the following:
 - a. the total training system concept, including embedded training;
 - b. the reasons training systems must develop within more general processes of materiel system development;
 - c. the effects of embedded training on this relationship; and
 - d. the content and uses of the remaining documents in the series, and their relationships to the training systems development and acquisition processes.
2. Volume 2: ET as a System Alternative provides guidelines for deciding whether ET should be further considered as a training system alternative for a given materiel system. It also includes guidance on consideration of ET as an alternative for systems under product improvement or modification after fielding.
3. Volume 3: The Role of ET in the Training System Concept contains guidance for the early estimation of training system requirements and the potential allocation of such requirements to ET.
4. Volume 4: Identifying ET Requirements presents procedures for defining ET requirements (ETRs) at both initial levels (i.e., prior to initiating system development) and for revising and updating initial ETRs during system design and development.
5. Volume 5: Designing the ET Component contains analytic procedures and guidance for designing an ET component concept for a materiel system based on specified ETRs.

6. Volume 6: Integrating ET with the Prime System contains considerations, guidance, and "lessons learned" about factors that influence the effective integration of ET into materiel systems.
7. Volume 7: ET Test and Evaluation presents guidance for defining the aspects of the ET component (test issues) to be addressed in prototype and full-scale system testing.
8. Volume 8: Incorporating ET into Unit Training provides guidance for integrating ET considerations and information into unit training documentation and practice.
9. Volume 9: Logistics Implications presents guidance regarding key logistics issues that should be addressed in the context of ET integration with prime item systems.
10. Volume 10: Integrating ET into Acquisition Documentation provides guidance on developing the necessary documentation for, and specification of, an ET Component of a prime item during the Army's systems development and acquisition process. This document discusses the Life Cycle System Management Model (LCSMM) and the Army Streamlined Acquisition Process (ASAP) and describes where and how to include ET considerations in the associated documentation. It also describes where and how to use the other volumes in the ET Guidelines series to generate the information required for the acquisition documentation, and provides guidance in preparing a contract Statement of Work for an ET Component to a prime item system.

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**IMPLEMENTING EMBEDDED TRAINING (ET): VOLUME 6 OF 10: INTEGRATING ET
WITH THE PRIME SYSTEM**

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IMPLEMENTING EMBEDDED TRAINING (ET):
VOLUME 6 OF 10: INTEGRATING ET WITH THE PRIME SYSTEM

INTRODUCTION

Current Department of the Army (DA) policy states that

...an embedded training (ET) capability will be thoroughly evaluated and considered as the preferred alternative among other approaches to the incorporation of training subsystems in the development and follow-on Product Improvement Programs of all Army Materiel Systems.¹

The policy, in effect, says that ET will be included in all new and emerging Army systems and as an alternative for existing systems under product-improvement or modification unless there are valid and compelling reasons not to do so.

The ET analysis process, which identifies the need for and the components of ET within the total training system configuration, has been documented in earlier volumes of this guideline series. In developing the guidelines and procedures for ET integration described in this volume, the authors have assumed that the need for ET has been identified. Thus, ET requirements (ETRs) are also known, although perhaps only at a very general level, and certainly are subject to change as the system design and description evolves. This volume is designed to identify key factors and decision points which must be considered in order to ensure the successful integration of ET with the materiel system.

Knowledge gained from ET evaluation and actual development on selected Army systems has provided lessons learned about the process of ET implementation and integration. It is from these lessons that much of this volume is derived. This volume provides guidance on how the hardware and software developers of the materiel system, and the training developers of ET, must interact at crucial decision points with regard to ET requirements. It precedes this guidance with brief tutorials to orient both materiel system and training developers in each others' field. The objective of the tutorials is to establish the mutual understanding required for effective interaction. The volume also identifies the questions that must be asked by government contract monitors to determine the quality of the interaction and the resulting decisions.

The development of the ET subsystem, i.e., the hardware, software, and courseware which supports the training, must coincide with the development of the major item, or prime system, since ET relies on the materiel system's hardware and software for its operation. Unlike alternative, traditional forms of instructional design, ET design decisions cannot be delayed until the major item is completed, and its hardware and software capacity is committed.

¹US Department of the Army (1987). Policy and guidance letter, subject: embedded training. Office of the Under Secretary of the Army, signed by General Maxwell R. Thurman, Vice Chief of Staff of the Army, and the Honorable James R. Ambrose, Under Secretary of the Army, dated 3 March 1987.

Successful ET development requires a coordinated team approach where team members are drawn from training developer (TD), combat developer (CD), and materiel developer (MD) communities in the Army, and from similar components of the contractor development team. This pool of prime system and ET developers must maintain communication throughout the materiel system development process. Training developers, whether part of TRADOC or members of contractor development teams, continuously must make tradeoffs to establish priorities in their effort to realize "ideal" ET. ET design tradeoffs span several levels of interaction: trainers' views of ET requirements are considered at the TD level; the user-system requirements are addressed at the TD and CD level; and achieving training, combat, and hardware needs in light of system limitations is considered at the TD-CD-system developer level. Throughout this process of tradeoffs which continues until the final system design is frozen, the TD must work with hardware and software developers to ensure that capacity to satisfy ET requirements is not diminished unnecessarily in light of system design tradeoffs.

Conceptual Structure for ET

The principals, components, and interfaces which define a conceptual structure for ET, exclusive of hardware, are shown in Figure 1. This figure also depicts: (1) the relationship between ET-implementing software and system operational software; (2) the relationship between ET and system software; and (3) courseware and support functions and responsibilities. The figure is a slightly modified version of one which appears in Volume 9: Logistics Implications of this ET guideline series (see Cherry et al., 1988).

Software is depicted within the left "box" in Figure 1. Two interacting software elements are shown: system operational software and ET software. The two entities are shown together to illustrate one of the logistic support implications of ET: all line coded software (for both ET and the operational system) should be maintained and modified in concert, and by a single organization. That organization is represented here as the appropriate system program or project manager's² (PM) organization, or that of the proponent readiness command for the system (e.g. Army Missile Command, Tank Automotive Command, etc.). ET courseware spawns related issues that have implications for system design. Current views toward ET implementation suggest that courseware will be more volatile and subject to change than either system operational software or ET-implementing software. This has two implications for design and logistic support. First, an ET component should be designed to accommodate variable courseware and rapid courseware modifications and updates, as is necessary to support effective and flexible training. Second, the courseware should reside in databases that provide essential

²Throughout this volume, we refer to the person leading the system development effort as the program manager. In reality, this person may be the program, project, or product manager, with the title corresponding to the size of the development effort (in budget, manyears, or other metric). Program managers are, in fact, leaders of major system procurements, such as for the FAADS. The PM for a specific FAADS system, such as the FAADS-LOS(H), is a project manager.

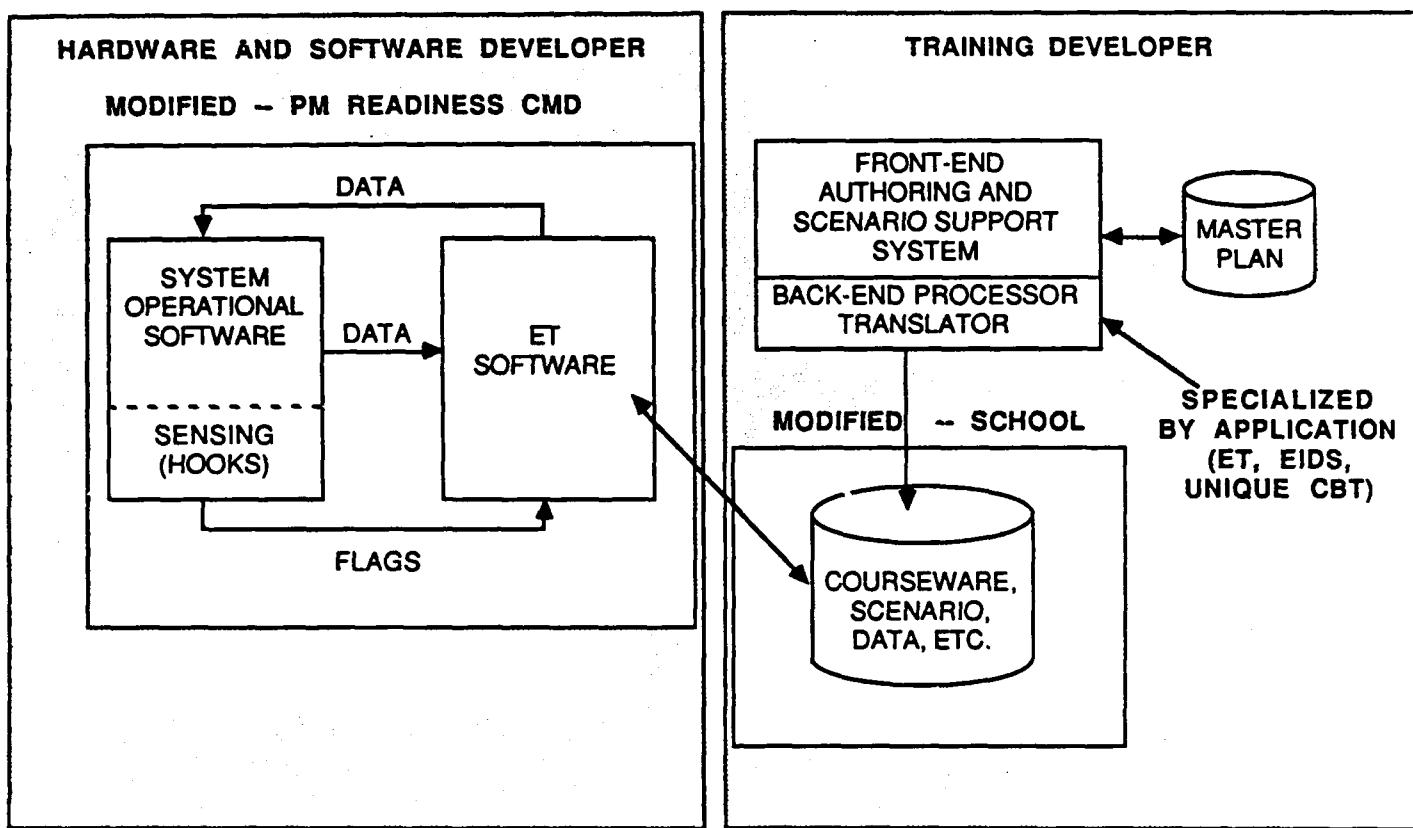


Figure 1. Conceptual Structure for Embedded Training (ET).³

³ Adapted from Cherry et al. (1988) Implementing Embedded Training (ET): Volume 9 of 10: Logistics Implications, ARI Research Product.

information to be acted on by software -- rather than as in-line coded software. This is shown in Figure 1 by placing courseware in a separate "box" from software.

Courseware development and maintenance have traditionally been the province of proponent schools associated with a system. However, as ET becomes commonplace and other specialized instructional media and approaches (e.g., Electronic Information Delivery System [EIDS], specialized Computer-Based Training [CBT], Conduct of Fire Trainers [COFT], etc.) mature, new courseware maintenance support will be needed. Figure 1 suggests an approach that may be feasible to support authoring for various media and training approaches. This approach employs a common, or virtual, "front-end" user interface for developing and maintaining courseware under the authoring support system. The "front-end" user interface would be able to utilize a number of "back-end" processors (e.g., translation software) to prepare databases (including courseware, scenarios, etc.) that support the presentation of training via specific media or training approaches. Extensions of this translation concept would also allow for porting applicable training software to application-specific devices, thus increasing the courseware's utility. This concept also incorporates code-translation or code-generation facilities for more than one variety of central processing unit (CPU). This facility could also allow the use of standard program-language-defined modules with multiple-CPU machines within the same operational system, as well as in inter-system arrangements.

The components in the left box are of interest to the PM's hardware-software developers, while entities in the right box are of interest to Army and contractor TDs. The primary interface between the two groups ties the TD's courseware to the ET software. Later discussion will clarify the interfaces which must be considered for successful ET implementation.

Intended Users

Several categories of users were considered in developing these guidelines for ET integration. This document is specifically intended to be of use to those who are actively involved in implementing or monitoring the process, have approval authority for the results, or who must be made aware of the results as they impact on their own activities. Specifically, this includes: (1) PMs responsible for the entire project (both combat and training developers); (2) system developers (both government and contractor) responsible for the hardware and software design and implementation; (3) training system developers (again, both government and contractor) responsible for training hardware and software, authoring system, and courseware development; and (4) logisticians responsible for supporting the total system throughout its life cycle.

Report Organization

The remainder of this volume is divided into two sections which cover specific ET system integration issues.

The next section, "Functional and Implementation Characteristics of ET," presents a descriptive model of ET from two perspectives: the training developer, and the hardware and software development team. Characteristics viewed by the two development communities are defined and a common vocabulary for communication among ET developers is described.

The last section, "Guidelines for ET Integration," outlines critical integration issues derived from lessons learned in the ET development process. It also presents a generic set of questions for the Army to ask at design reviews to ensure that progress is occurring.

FUNCTIONAL AND IMPLEMENTATION CHARACTERISTICS OF ET

Previous volumes in this embedded training (ET) series have addressed procedures and guidelines for establishing the need for ET, identifying the tasks to be trained, and developing an ET design concept. ET, more than any other training media, must be developed concurrently with the prime system,⁴ with special effort made to ensure communication among parties at all stages of design decisions. The purpose of this document is to identify locations where communication must occur in order to ensure an effective ET implementation.

The integration of ET into the system design and development process requires a diverse set of players on both the Army and contractor side. In the early stages, they must work together to define ET requirements (ETRs). If ET is to work, the training developer (TD) must play a larger role than traditionally assumed. Once the program manager (PM) or Program Executive Officer (PEO), takes over and contracts are awarded for materiel system development, the key is knowing what information is needed to monitor progress and evaluate product effectiveness. In addition, the project manager, in his role as hardware system developer, must now wear two hats: those of prime and training system developer. The latter hat is new and takes some getting used to. The PM must work closely with hardware and software system developers (SDs) in both government and contractor communities. It is the project manager's job to keep all players in step and on course toward the appropriate system development milestones.

The remainder of this section will describe ET characteristics which are of particular importance to the training developer and the hardware and software developer. The intent is to establish vocabularies which are jointly understood by these persons, thus facilitating communication among development team members. Those readers who would like to begin with a brief overview of what can constitute ET should first review the Appendix.

ET from the Training Developer Standpoint

The TD is concerned with designing and providing sufficient training to ensure acceptable soldier-system performance when required in combat operations. ET is one of several components of the training system. It possesses attributes of traditional training but, as the definition

⁴For the discussions in this volume, "prime system" refers to the Army materiel system, or major item being designed, developed, and acquired. It may represent a complex, multi-component item such as an M1 tank, or a relatively simple item such as a command and control station. What these systems share is the presence of computer hardware and software to support training. The operational system refers to the prime system configured to perform its stated mission, in non-training operations.

implies, provides the training on the prime system itself. The possible attributes of ET are: embeddedness, stimuli generation and presentation, response trapping and processing, evaluation, diagnosis, remediation, adaptivity, and management. The extent to which each of these is feasible will be system-specific. Even limited ET (i.e., ET possessing a subset of the above attributes) is worthwhile to consider. Full ET supports the complete set of training capabilities. Useful training also can exist, however, through limited ET components, such as ET which supports only limited practice. The objective in developing ET must be to achieve the maximum training that is consistent with the requirements, cost, and feasibility of the operational system.

Since the implementation of these attributes within the ET hardware and software subsystem will impact the operational system, they should be clearly understood by the SD, combat developer (CD), PM, and contractor personnel involved. Each attribute is defined and described below.

Embeddedness

ET must occur using the prime system's operational equipment. The following discussion treats ET integration regardless of the design approach. Fully integrated ET (i.e., ET which is fully integrated with the tactical system software and equipment configuration) is the more demanding of these from a design integration standpoint. Appended ET relies on additional equipment (e.g., processors, display generators, etc.) to provide the training. In any case, training and assessment is provided by the ET subsystem through the prime system's soldier-system interface. Once ET is invoked from the operational software with appropriate commands, the ET software is responsible for playing or running the training courseware. A high degree of interaction is required among ET and system software to access and transfer data among appropriate sensing mechanisms, hardware devices, operational and training software modules, and training management routines during and immediately after training.

Stimuli Generation and Presentation

A mandatory feature of ET is the ability to provide stimuli necessary to support training. Stimuli are those events present in the system and perceived through the primary sensory modes of the soldier (i.e., sight, sound, touch) which would also trigger some soldier response, whether immediately overt or not. ET must generate and produce, on appropriate media, the necessary stimuli. These stimuli range from displaying text on the operational display, to sounding auditory alarms or signals, to illuminating programmable or status display indicator lights, to presenting continuous, direct, or indirect views of the external environment (as seen through periscopic or telescopic views, vision blocks, or display screens or other indicators).

ET opportunities are increased when the input stimuli are presented and processed electronically. The nature of stimulus generation in the prime system, and the ease with which these events can be simulated in training, will strongly influence the scope of the ET provided.

Response Trapping and Processing

Just as the nature of the input stimuli is important to the TD, so is the nature of the operator responses. Results of response trapping and processing essentially trigger the evaluative, diagnostic, remedial, and adaptive features of the training. Consequently, the scope of training, beyond simple drill and practice, is affected by the training system's ability to trap responses and evaluate them. Where response recording is possible, but evaluation is not, as with verbal communications, sophisticated AI techniques may be necessary, generally at greatly increased cost and overhead. The possible scope of ET is strongly influenced by the capability of the prime system's hardware, software, and interface control architecture to support operator-initiated events, and by the nature of the tasks to be trained.

Evaluation

ET should provide the TD with the capability to evaluate the trainee's performance through specific tests and the resulting scores. Scores could be based on percentage correct, time to complete, or other appropriate measures. Criteria for passing the tests and advancing to subsequent lessons, (e.g., "percentage greater than 90," or "time less than 60 seconds") are also necessary. Some recordkeeping is also desirable to save scores or other diagnostic data for later analysis. The nature of the soldier's task will define the most appropriate evaluation; system storage capacity and ET algorithms and courseware features will define the evaluation features actually available.

Diagnosis

The TD must diagnose errors and incorrect behavior to ensure that correct trainee performance is achieved (and training is successful). The ET software must provide courseware drivers to present appropriate training materials, and to prompt for and react to trainee responses. Example features include displaying sequences of text or multiple choice questions, or prompting for a response to an illuminated programmable function key. The operational software must provide appropriate linkages or hooks to permit response gathering. This is an especially difficult activity in the case of mid-course diagnosis during continuous tracking tasks, particularly if several correct solutions exist, or more importantly, the operational software was not designed for such outside intervention.

Simple discrete actions on the part of the trainee, such as depressing a key in response to a displayed question, activating control buttons, or identifying targets as friend or foe, especially those which result from procedural training tasks, are easier to diagnose than complex continuous actions where several correct paths or solutions exist. The latter actions, such as navigating and controlling a remotely piloted vehicle (RPV) to target, pose questions to the trainer as to where, when and what determine an incorrect behavior. Diagnosing errors in navigation during a continuous activity assumes that correct courses are available for comparison, and is much more difficult in terms of memory or processing resources than diagnosing the final event (e.g., successful contact with target, within time and fuel consumption criteria, and avoidance of counterattack).

Remediation

Remediation provides the TD with a means for correcting incorrect performance, manifested through incorrect responses to training activities. Remediation is the primary mechanism for achieving adaptive branching. As with adaptation, remediation varies in complexity. At one extreme, remediation is limited to the trainee receiving feedback explaining errors that have been committed. In a more sophisticated version, feedback would be followed by inserting a remedial activity into the normal session flow immediately following the failed activity and feedback message. Normal training resumes at the branching point, on completion of the remedial activity. In an even more flexible case, remediation activities are chained, allowing the entire session context to be adjusted. Here, if a training activity has failed, the trainee could be placed in a completely different training sequence in a different lesson. The normal session flow would then continue from the context of the new lesson. The complexity of the remediation provided by the courseware is limited by the sophistication of the ET software itself.

Adaptivity

A desired feature of ET, as a form of computer based training (CBT), is its potential for individualizing the training to the user, and thus maintaining the trainee's interest throughout training. Individualized, or adaptive, training responds to student responses and changes pace, content, or emphasis, based on the responses or learning style of the individual. The adaptivity of CBT to trainee responses ranges from minimal through highly flexible. Repeated presentation of training material in drill and practice CBT is an example of minimal adaptivity. Training which presents different tracks of material for instruction according to the trainee's response is an example of maximal adaptivity. The latter author-driven technology is commonly referred to as branching computer-aided instruction (CAI). An extension of CAI which adapts and alters the instruction to the idiosyncratic responses of each trainee is user-driven intelligent computer-aided instruction (ICAI).

The degree of adaptivity incorporated into the ET will depend on the creativity of the author, and on the capability of the authoring support system, courseware, and ET software itself. To accommodate user-control, the highly adaptive ICAI will require sophisticated knowledge engineering or artificial intelligence (AI) features.

Management

ET management considers the schedule of training delivery to an individual or crew, and the management of training within a unit. Training recordkeeping within and among trainees must be considered. Different features are required for the two aspects. For the former, the TD is concerned that the trainee progresses through lessons and is able to enter directly into specific lessons at successive training sessions. This implies that trainee recordkeeping is available within the system to monitor trainee progress, completion, and scores. To manage multiple trainees, the trainer needs reports of scores, by lessons, to identify

deficiencies and strengths, and suggest remediation through other training components (specialized drills, media center, exercises, etc.). Scoring criteria will vary with the type of skills being trained and the type of responses being recorded. The scores may be as simple as percent correct, or may be complex time lines of trainee responses versus mission events. Training management requires score keeping and tallying features within the training software, and access to auxiliary mass storage devices (e.g., winchester hard disks or removable cartridge media) to maintain student records for both trainee and trainer use.

ET from the Hardware and Software Team Standpoint

Once the PM has taken control of the system development effort, the ET subsystem requirements and impacts must be established in light of the total system. While the training developer is concerned with providing training to ensure acceptable soldier-system performance, the system designers are concerned with ensuring the operational effectiveness of the system itself. Obviously, the two objectives are interrelated, and the system design must be sensitive to both of them.

ET impacts the operational system design in several key areas. Among these areas are: the ET executive, courseware algorithms, data, and courseware authoring language; system device interrupts to present stimuli and trap responses; processors; storage capability; the soldier-system interface (SSI); and the soldier task definition. Each of these will be defined and described in this section.

The interaction among the ET executive, algorithms, data, and courseware is worth mentioning before describing each area individually; this interaction is presented in Figure 2. The ET executive is the primary control mechanism of the ET subsystem. As such, it reads and responds to commands and related parameters from the courseware algorithms. The executive serves as a transfer mechanism for training data, such as trainee status records, and passes them to the courseware algorithms, or updates the data as directed by the algorithm interaction. The degree to which the training data alters the sequence of training lessons based on student performance is related to the adaptivity of the training system, as discussed in a previous subsection on adaptivity.

ET Executive

The ET Executive is the software mechanism by which the training courseware is controlled and presented in the prime system. It provides the top-level control between trainee, author, and operational system actions. Since the ET executive must be able to accept a wide variety of subject-matter-specific training software, it should be designed with flexibility and extensibility in mind. A modular design will allow it to accommodate new training features and capabilities demanded of a rich authoring domain and changing operational mode. The executive must provide several basic training features to the author: (1) deliver a sequence of training activities in the order specified by the author; (2) present items under menus, defined by the author, and selected by the trainee; and (3) maintain performance records for training activities and deliver remedial training activities as specified by the author.

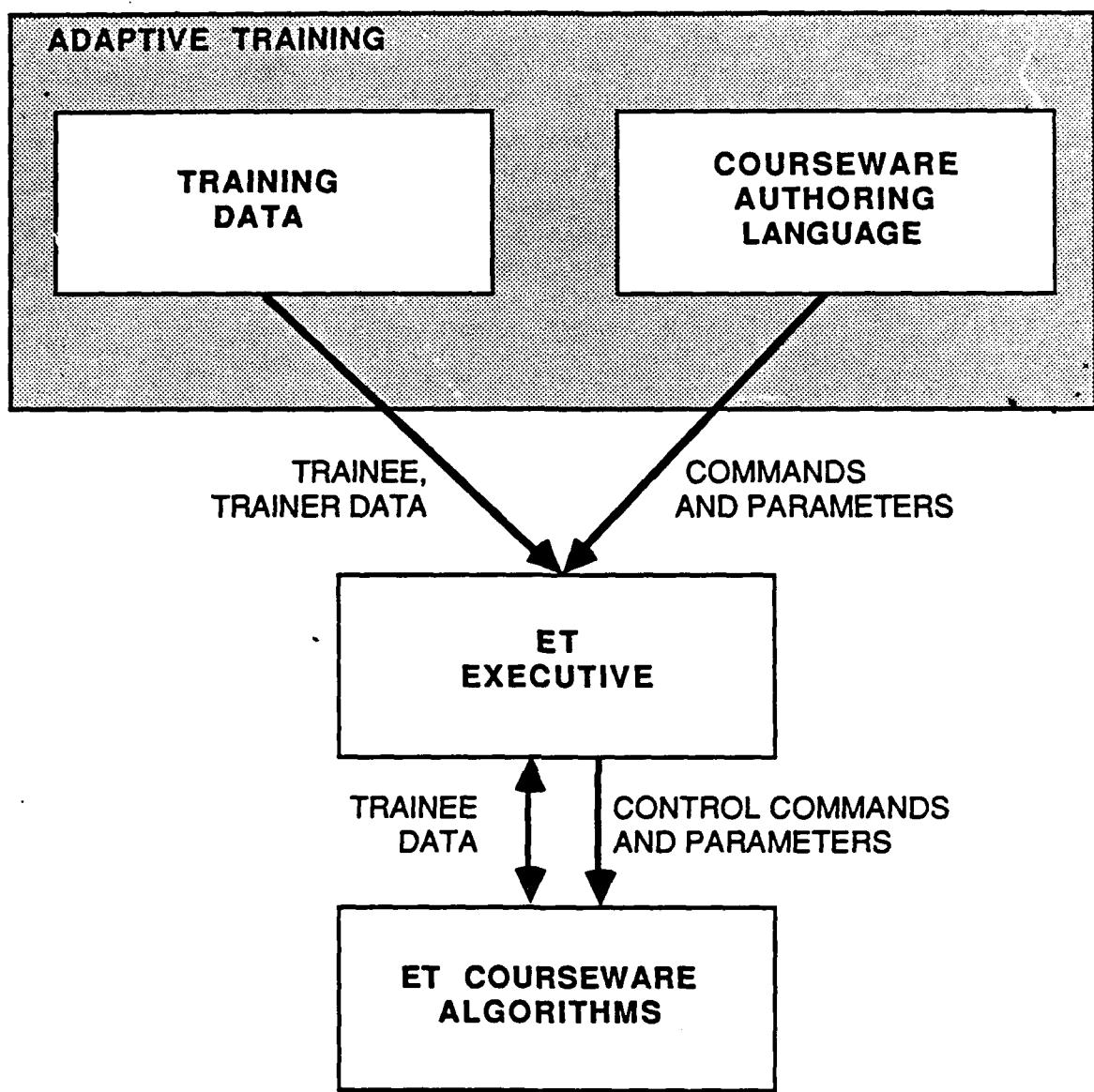


Figure 2. Interaction among ET Executive, Algorithms, Courseware, and Data in the ET Subsystem.

Serving primarily as a pass-through for the courseware, the ET executive software is highly control-intensive. Consequently, it is advisable to separate the author-initiated session control, defined by the courseware and algorithms, from the trainee-initiated control (i.e., trainee commands to move forward and backward among lessons, video frames, or to exit training) (see Farmer et al., 1987). This control is chiefly within the training software. Courseware control of the operational software is achieved via the courseware algorithms discussed later.

The executive interfaces with the operational system's task or function scheduling services and its device drivers. Through the device drivers, the executive is able to control both display devices for training menu presentation, and primary input devices, such as the keyboard, for menu or command selection. Within the training software, the executive interacts with the training courseware algorithms and device drivers. It also relies heavily on data storage devices for saving and retrieving trainee status, scores, and courseware data.

ET Courseware Algorithms

The ET courseware algorithms define the training or courseware implementation procedures which are invoked under the control of the ET executive. The algorithms, in effect, drive specific training functions and address specific training requirements, as defined by the training or courseware developer. The algorithms vary among training applications based on the courseware which is being presented. Sample training algorithms range from basic CAI drivers which display text, drive video sequences, simultaneously display static graphics and sound, or graphics and text, or establish multiple choice pools, to more sophisticated drivers which provide real-time simulation and diagnosis of navigation or tracking tasks.

In addition to their interface with the ET executive, the algorithms may also share processing tasks and data with the mission-oriented algorithms of the operational software. For example, a courseware algorithm to train route planning skills may interface with related mission-specific tasks to identify way points and rank the route based on pre-defined criteria. These algorithms would also be responsible for engaging and disengaging operational subsystems for purposes of system safety. For example, they would instruct the operational system to disengage turret rotation and engage gun elevation mechanisms during target tracking tasks.

ET courseware algorithms represent the key building blocks for implementing the ET courseware within the prime systems operational software. They share control and data at many levels: with the ET executive, the operational software algorithms, and the system and training-specific device drivers.

ET Data

ET data provide the information for status and control among ET and operational software components. This includes status and trainee data

passed among courseware algorithms, device drivers, and operational software routines. Also included here are special training data used to emulate secured operational databases, such as those occurring in communication, command, control and intelligence systems. While the ET algorithms provide the framework for linkages between training and operational software, data passed between the modules is essential to effective ET evaluation, diagnosis, remediation, and adaptivity. Particularly in highly adaptive systems, the data will also direct the training courseware to match the individual trainee's abilities and performance. Training management data maintains the profile of overall high scores, as well as training status, scores, and lessons completed for individuals. Scoring algorithms which map subject-matter-specific data into standardized percent or time scores are also considered here. Internal data structures and auxiliary data storage formats must be defined and maintained to be consistent with the overall operational and training software design.

ET Courseware Authoring Language

ET courseware authoring language is the medium by which the author directs the ET software to provide specific soldier training on the prime system. It consists of specific instructions for the ET executive, and for the courseware algorithms, to organize training into lessons, present training materials, and direct feedback and remediation based on trainee actions. Of the various components of the ET subsystem, the courseware will undergo the most changes in an effort to adapt to changes in the operational system and its operating environment. Consequently, it should be represented within the training system in databases which can be updated independently of the operational or ET software itself. It must be selected or designed in conjunction with the ET executive and courseware algorithms to ensure that all instructional and mission-specific functional features (e.g., video playback, multiple choice question pools, video and sound or text overlay, function key illumination, navigation control and interrupts, etc.) are available.

Device Interrupt Drivers

Device interrupt drivers are the basic service routines which handle communication between the specific hardware components and the combined operational and training systems. From the ET standpoint, they play a critical role in facilitating stimulus presentation and response trapping on a range of system sensor devices (e.g., analog and digital displays, function keys, controls, keyboard or joystick responses). Drivers may also apply to ET-specific devices when simulated stimuli are necessary for training. Examples of this are drivers for accessing video disk players containing target imagery, or perspective imaging systems for computer-generated views of three-dimensional terrain used in navigation training.

Processors

The computer-driven orientation of ET and its relationship to the operational system necessitate careful consideration of the processor facilities provided to accomplish both training and operational system objectives. Multiple processors are often employed throughout the prime

system, each with a specific processing objective. The central processing unit and the interface architecture control processor execution. The processor and memory requirements of the integrated ET subsystem must be considered and weighed along with those of the operational system. This includes sufficient capacity to load and execute the ET executive, courseware driver algorithms, device interrupt modules, and memory resident data (e.g., courseware or trainee status data). ET implementation requires considerable computer capability. It also requires interfaces to the prime system equipment (e.g., sensors, displays, controls, etc.) and with operational software. The actual capacity demands are determined by the tasks to be trained, and the modes of stimuli and sophistication of the simulation. Constraints imposed by the prime system, such as volume, mass, and power, may restrict ET capability. It is critical that providing ET neither detracts from nor interferes with the operational system's mission performance. Maintaining mission performance and system safety during training mode may well require additional processing capacity to permit sufficient fail-safe procedures (e.g., weapon system activation overrides, turret slew, etc.).

Once established, ET memory or processor requirements must be carefully considered throughout the development effort. Since the ET software will often be executing within the context of the operational system, combined memory and processor requirements for all necessary routines should be considered. ET requirements and the consequences of change should not be compromised beyond acceptable limits as alternative designs are considered during the operational system development process.

Storage

In order to support training management functions, the prime system must have sufficient storage capacity for recordkeeping, evaluation, and training courseware lessons. Memory must be more than customized read-only memory (ROM) chips to permit both read and write capability. Resident and read-write mass storage memory are considered.

Soldier-System Interface

The soldier-system interface (SSI) provides the means for soldier communication, control, and feedback with the prime system. Overall and subsystem status are presented to the soldier through an array of direct and indirect visual displays, as well as auditory and tactile means. Soldier control is achieved through a battery of input devices, ranging from manual control sticks, to verbal communication, to control activation. The type of information and the means for transmission all contribute to the SSI.

Just as the SSI is the primary means of soldier communication with the operational system itself, it is also the primary means for delivering ET on the prime system. Thus, the same factors which define the SSI also strongly influence the opportunities for ET. Simulating a virtual environment, such as appears on CRT radar screens, is much easier than simulating 3-D direct view visual terrain. Similarly, control lever activations and discrete system responses are easier to trap and evaluate than verbal protocols.

ET opportunities are increased when the input stimuli are presented and processed electronically. Visual stimuli, either through indirect sights or computer controlled indicator displays, and auditory alarms, can be simulated for training purposes, while mechanical displays, direct views of the environment, dynamic environmental forces (e.g., acceleration, rotation, etc.), verbal communications, or olfactory (smell) or tactile (touch) simulation are difficult, costly, and often not even feasible. The training and mission performance implications of the prime system's candidate technologies and design approaches should be considered in the requirements integration phase of design. Perceived difficulties should drive the design to improved system solutions which benefit mission performance as well as ET.

Opportunities for ET are also increased when the response media, or output mode, facilitates trapping and evaluating responses. ET implementability must consider both capabilities within and outside the mission system. This opportunity may exist either on-line, via adequate processing capacity within the prime system, or off-line, through adjunct facilities which provide specialized training support, such as with AI processors located off-line for performance assessment.

Electronic media are preferred. Responses considered easy to record include discrete and continuous electrical control movements, while control movement supported by hydraulic or mechanical media requires additional instrumentation and transducers to trap responses. Evaluation is easiest with discrete control movements, such as setting a switch, or pressing a trigger, and increasingly difficult with continuous movements (e.g., tracking tasks), or cognitive processes, verbal communications, or complex tasks. Where response recording is possible, but evaluation is not, as with verbal communications, either instructor presence or AI techniques may be necessary if training beyond practice is to be achieved. Both alternatives generally are associated with increased cost and a diminished opportunity for on-line ET evaluation.

Soldier Task Definition

Soldier tasks are defined by the nature of the operational mission and the SSI. These same tasks form the basis of the tasks to be trained. The nature of the tasks, in terms of their complexity or information processing requirements significantly influences their likelihood as ET candidates. Perishability of complex tasks makes them likely candidates for training, but the difficulty in assessing and evaluating performance of complex cognitive tasks limits the range of training capabilities that can be provided by ET but certainly permits at least an ET capability.

Changes in the mission, the operational system, or the SSI will effect a change in the soldier task definition. From a training context, this will necessitate a change in the training courseware database, or, if the change is major, may also require changes in the ET executive and courseware algorithm software. Obviously, the latter carries with it a much greater logistic implication for updating and promulgating changes to the software and related programmable ROMs, while the former change in courseware may be affected by populating a new database or inserting a new media cartridge.

The ET-Prime System Interface

Two areas of ET integration have emerged from the above discussion. The first is the relationship between the training attributes of ET, as defined by the TD, and the hardware and software implementation. The second area addresses the interaction between the ET subsystem and the prime system's hardware and software.

Components of the hardware and software system relevant to training attributes were mentioned in the subsection titled "ET from the Training Developer Standpoint." These interactions are also presented in Figure 3. Note that ET-specific implementation areas, i.e., the executive, algorithms, data, and courseware, are grouped together, and interface with all attributes. Of the remaining implementation areas, that of interrupts is most closely tied with training attributes. The prime system's capabilities for presenting stimuli and trapping responses strongly influence the degree of embeddedness, diagnosis, and remediation provided within ET.

ET hardware and software development cannot be performed independently of the prime system, largely because of the significant interdependencies between the two. Nor can it ignore the options for ET functionality which are provided through off-line support processors. Fully embedded training must operate in concert with the prime system. This interaction may take on many forms. At one end, with fully in-line operation of ET, the ET software and hardware share common modules and devices with the operational system task structure. At another end, ET shares the operational hardware and possibly the host operating system, but relies on its own version of the relevant operational software algorithms, drivers and data to emulate the operational system's functionality.

The primary components and areas of interaction in ET are indicated in Figure 4. The arrows indicate flow of control and data between components. Horizontal and diagonal arrows indicate transfer of control or data between the ET subsystem and the prime system. The greater the interaction, as in the first example listed above, the more active the interaction represented by the arrows. In the latter example, where ET shares the operational hardware, but few of the software algorithms, the horizontal arrows are less important. Vertical arrows exist in either case.

Hardware and software developers must be aware of the interactions and the implications on design decisions. They must also be in constant communication with prime system contractor, and government and contractor TD parties to ensure that the attributes of the ET subsystem are compatible with the functional requirements for training. The following section will present generic questions which should be addressed throughout the design process, and specifically at design reviews, to guarantee that ET is proceeding according to stated objectives.

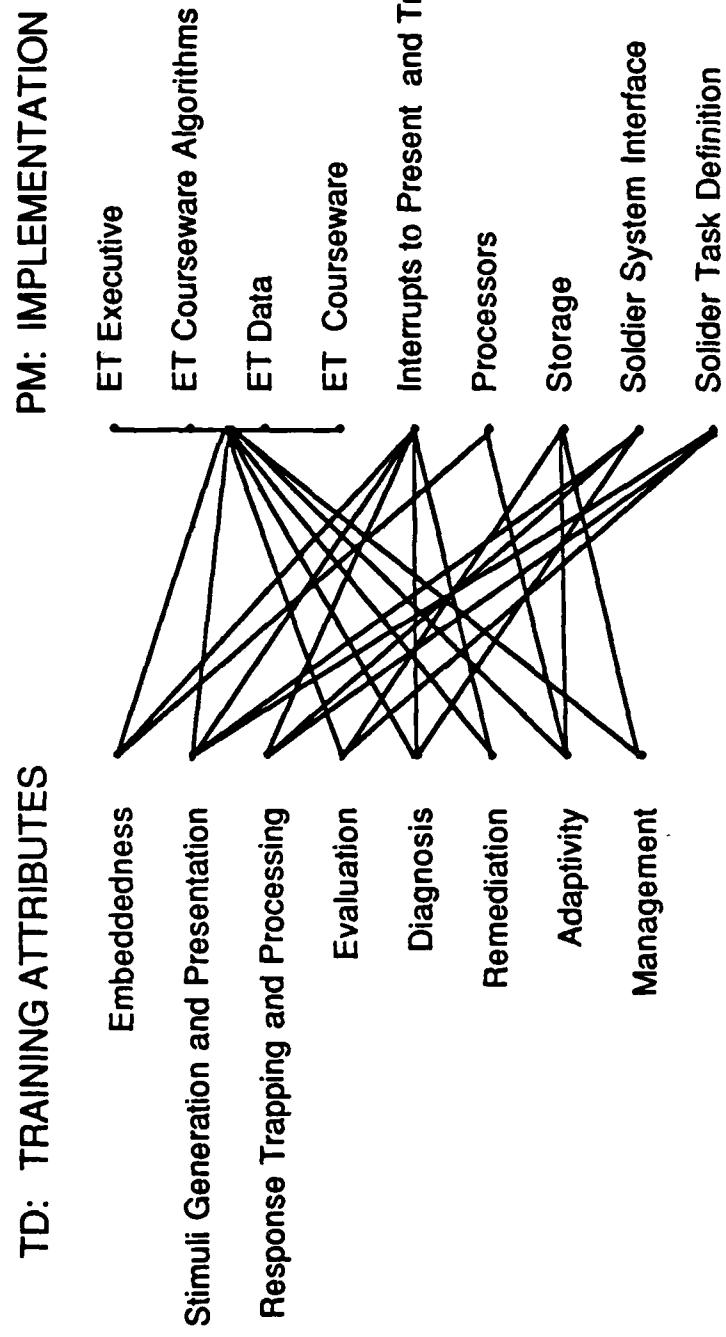


Figure 3. ET Perspectives: Parameters and Interactions.

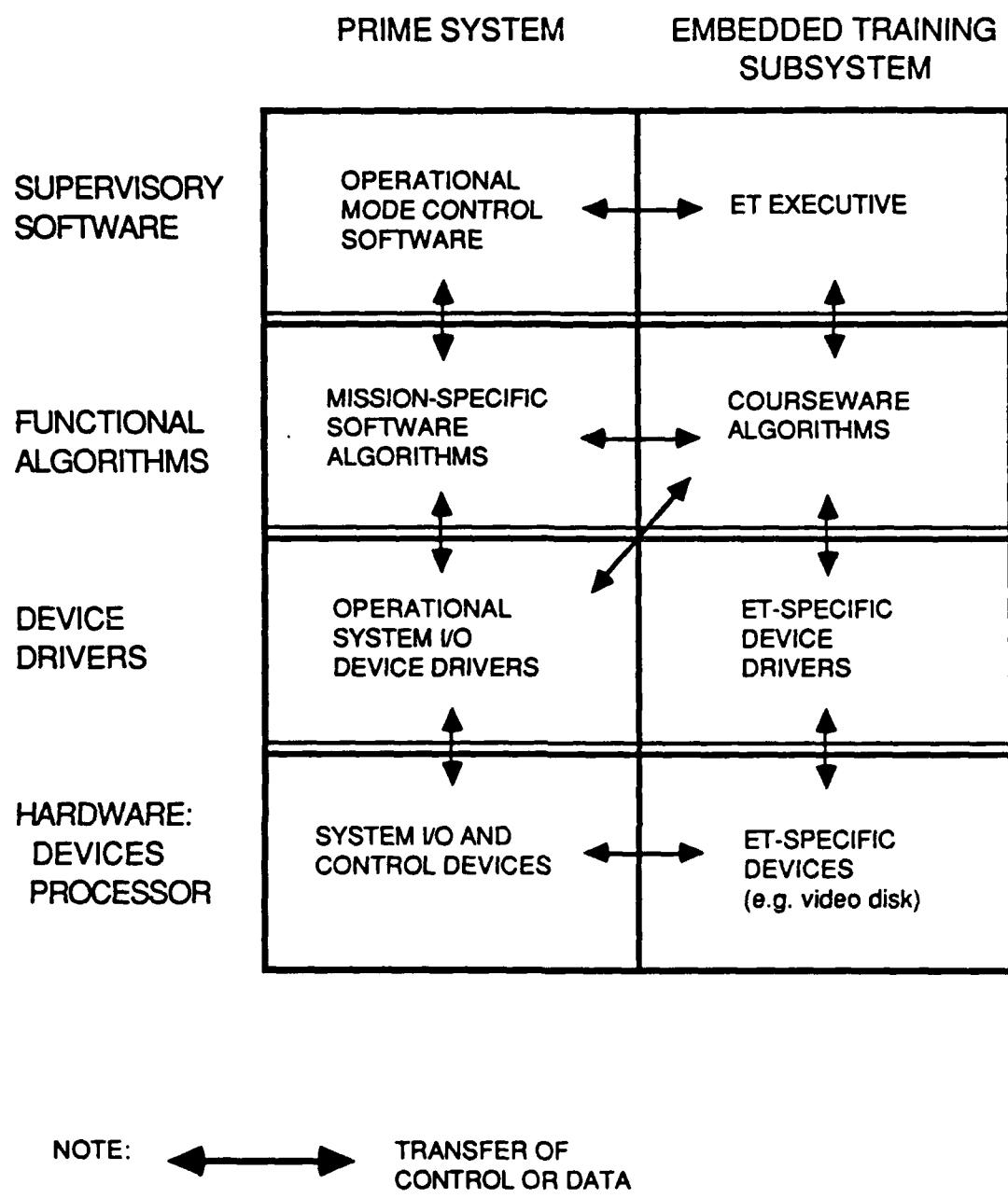


Figure 4. Hardware and Software Interactions in ET.

GUIDELINES FOR ET INTEGRATION

This section presents the key issues which must be addressed in order to ensure the successful integration of ET with the prime system. The issues are organized as questions, derived from the parameters, components, and interactions outlined in the preceding section, which must be asked by the Army at critical project design reviews. Questions are grouped into four areas of concern: integration management, the soldier system interface and task description, hooks for ET and prime system integration, and physical system requirements. Questions are accompanied by additional issues derived from lessons learned during previous ET development activities.

Integration Management

Key management questions are:

- How is the design team staffed and organized?
- and
- What mechanism is provided to describe the total software package?

An overriding issue throughout the ET implementation process is the need for close contact and cooperation among all system development team members. This includes training developers as well as members of the hardware and software development effort. As the program manager (PM) assumes management responsibilities, a management plan is necessary to outline team interactions and inform parties of resource requirements. In particular, who, what information, from whom, when needed, and the resources required to obtain it are critical. Both government and contractor parties must be constantly updated on developments and changes.

ET and prime system development should be merged into one acquisition program to ensure that functional requirements, hardware suite configuration, and software architecture will consider the total system, including the ET components. This integration will include ET considerations in the design tradeoffs for the system (e.g., modifications to operating system and support modules should consider the impact on courseware flexibility and on procedures required to initialize training (such as reloading training from cartridge media for each session)).

The key issue for both the "doer" and the "monitor" is to have available a mechanism which describes the total software package: the integrated set of instructions and data which describe operational and training functionality, implementation, and interfaces, as well as relationships to the hardware. This is nothing more than configuration control imposed upon a single integrated system. Any methodology which defines input-process-output and flow of control will suffice provided that it is followed and managed closely. The software developer, that is the single manager, must have responsibility and authority over both operational and ET software development. Ideally, he should manage a single integrated team. Appropriate use of configuration control and integrated design documentation will support this management and provide

Army monitors with a detailed view of training system progress, operational system progress and the degree to which the two are fully integrated in the prime system. The items of concern for integration management include the:

- operational system algorithms,
- training system executive,
- training system algorithms,
- common software,
- operational data,
- training data,
- common data,
- insertion and capture interrupts,
- processor budgets,
- memory budgets, and
- input and output (I/O).

ET developers must be made aware of all contemplated changes to the prime system in order to participate in the tradeoff process and to adjust the training product. A lack of interaction affects both the final form of the training system and the efficiency with which the training is developed. To take advantage of shared information, the ET development program must have schedule, resource, and design approach flexibility to adapt to changes in the design and schedule of the operational system. Sufficient time and dollar resources must be provided for the ET program and the contingencies of changes. Cost estimation for the design and implementation of ET within specific systems is difficult to establish. As experiences with ET increase and more historical data are available, the process will become easier and more accurate.

Soldier-System Interface and Task Description

The primary questions for the Army to ask are:

- Do the training developers (TD) and the hardware and software system (SD) developers have the same view of the soldier-system interface (SSI)?

and

- Do the TD and SD have the same view of the soldier tasks?

A common complaint raised by ET developers is "we were too early and too late." Designing training before soldier tasks are firmly established is difficult, at best. Yet some effort must be made to identify the nature of the tasks and establish bounds for the training concept. Waiting until the tasks and SSI are established is waiting too long. By that time, the physical system capacity has been defined and most likely allocated to tasks other than ET. Trying to obtain ET resources at that time is nearly impossible.

ET system requirements must be considered during pre-design concept studies if ET is to become a meaningful reality. Decisions regarding ET integration must be made early in the prime system design process to guarantee adequate resources. In the early stages of design for emerging

systems, however, one must make assumptions about the system and the associated training requirements in order to develop an ET design concept. A detailed concept must be produced as early as possible, touching on all issues that pertain to the ET component of a training system. In cases where information is lacking, assumptions, clearly labeled as such, may be made to produce a complete concept. The design concept must be revised once updated data are available. The design concept must contain a discussion of the training issues which will be addressed and augmented in future revisions. This initial design concept guides the decisions regarding training content when ET is actually produced.

The dynamic nature of prime system design guarantees that the system interface will be modified. Rather than waiting until the design is frozen and all documentation is available, the ET integration concept must be based on information and assumptions about the soldier-system interface and soldier tasks, and an overall understanding among parties to inform all involved of any design changes. Unfortunately, documentation, especially in the early stages of development, can rarely stand alone. Consequently, the ET and operational system developers must maintain close communication to gain timely and complete understanding of both the soldier tasks and soldier-system interface as they impact further design decisions.

ET and Prime System Integration Hooks

One of the Army's key integration questions, asked to ensure that adequate provisions exist in the operational software to invoke ET, should be:

- Are the ET hooks⁵ in the software defined and implemented?

The design and specification of the ET subsystem is closely tied to the prime system architecture and functionality, especially when determining appropriate hooks for invoking the training tasks. Prime system attributes, such as host operating system, task scheduling capability, network communication, and device interface protocols and drivers, in addition to the system's functionality and operational mode all affect the ET subsystem design. Several design approaches exist: (1) ET emulation of operational software, (2) ET invoking a copy of the operational software; and (3) fully integrated courseware controlling the operational software.⁶ The selection of a specific approach is largely driven by the system attributes presented above. Each approach is discussed briefly below.

⁵ET hooks are provisions (e.g., subroutine calls or task schedulers) in the prime system software to invoke ET functions or processes during training mode. These provisions should allow for data transfer and coordinated chaining to occur between operational mode and ET tasks, and provide for a graceful return from ET to the operational mode.

⁶Throughout this discussion, ET encompasses the full breadth of training delivery options including computer-assisted instruction (CAI), simulation, part-task, and full mission training.

For ET to emulate the operational software, the prime system's I/O screen design, communication protocols, controls, device parameter settings, and environmental variable settings must be thoroughly and correctly documented. The burden is put upon the courseware to simulate those portions of the operational interactions necessary for instruction, practice, and evaluation.

In the second option, where ET invokes a copy of the operating software, the prime system's software must be well documented. In addition, the I/O for each program must be structured or compartmentalized for ease in use, the setting and expectations of data requirements and environmental variables must be well defined, and data and control passed between programs must be well documented. The courseware must be able to invoke the component programs of the operating system and duplicate modules independently of the operational software to simulate real interaction.

In the last option, fully integrated training courseware runs with the operational system. ET courseware algorithms must be able to schedule or call operational algorithms, with control returning to the courseware calling routines for evaluation, diagnosis, or remediation. Controlled interaction with the prime system's operating system and tasks is required. The critical region where most of this interaction takes place is at the second level in Figure 4 (see preceding section, "Functional and Implementation Characteristics of ET"). Clear-cut operational or mission task boundaries with appropriate data flow are critical for providing hooks to the ET tasks.

Consider a simplified case of mission planning as an example. The mission is composed of two separate tasks: target identification and route identification. It is important that the operational software defines the mission as two tasks rather than one. During operational-mode trials, tasks are executed in series. During training mode, however, special training diagnosis, evaluation, and remediation functions are interjected after each task to assess soldier performance. The ET software must have the opportunity to change the flow of tasks in support of monitoring and control, while maintaining system security and safety. Clean task boundaries, available status or system mode data, and task scheduling capabilities are essential.

Courseware developers, the prime system developers, and the ET subsystem developers must all participate in specifying functional training and performance data requirements and task boundaries. After the functional requirements are specified, the interface software design and code are produced by the ET subsystem developers while working with the operational hardware and software developers. The functions provide capabilities to invoke the operational software, to send data to it, and to receive data from it. They define capabilities to store and restore operating system environments and terminal states; to search and store I/O streams and to synchronize timing between the ET and operational software; and to accept input streams from and direct output streams to a terminal. From these functions, the users' interactions with the system can be controlled, monitored, or restricted.

Without detailed knowledge of the prime system's hardware and software, it is difficult to pinpoint where hooks must be placed between the training software and the operational software. Hooks imply both specific interface components, at the level of individual screens and the input data required of the trainee, and features in the software to allow the ET software to stimulate the operational software. Hooks for software interactions can be defined once potential soldier-system tasks and interfaces are known.

Physical System Requirements

The primary questions the Army must ask to identify the capacity of the physical environment for ET are:

- Is there enough storage to do ET?
- Is there enough CPU capacity to do ET?
- Is there provision for ET I/O?

Most prime systems are designed with the capacity to handle only the programs and data of normal operation. ET resource needs must be incorporated in the calculations of initial system capacity in order to be included in the resulting determination of system reserve. This planned design reserve historically is consumed by new or additional functions or data before the system is completed. When the reserve is exhausted, cost and functional justification, as well as physical power and space constraints, become paramount issues in the system design decision process.

ET implementation requires system capacity in excess of that required for regular operations. This capacity must be identified, acquired, and dedicated to ET (not reallocated to operational system needs). The requirements must be identified in the pre-design concept exploration phases. Guaranteeing adequate ET capacity has implications on disk storage for training courseware and trainee recordkeeping databases, and for the storage of ET software itself.

In database intensive operations, heavy operational demands are placed on the primary system's host database computers. Early requirements identification can ensure that adequate resources are allocated for both operational and training requirements, allowing resident training databases to be co-located on the computer's hard disk. In systems where security is a key issue, such as intelligence gathering and analysis, duplicate training databases are required to enable the trainee to actually modify the database. Dedicated training databases on either hard-disks or removable cartridge media are possible alternatives. Providing the physical storage capacity for such duplicate databases might be one factor which drives the storage issues raised earlier.

Decisions regarding physical requirements of ET must be considered an integral part of the system requirement. Design tradeoffs must consider, nonetheless, the constraints of physical space, weight, and volume in the prime system. In addition, logistical consideration of supporting the equipment and software should be weighed. Other volumes in this series address these issues to a greater degree.

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APPENDIX A

ET: DEFINITION AND FUNCTIONS

An operational definition of ET, used throughout these volumes, considers embedded training to be:

...training which results from the use of features incorporated into the end item equipment, i.e., the operational system, to provide training using the end item equipment. Features include stimuli necessary to support training and should include: (a) performance assessment; (b) feedback consistent with reinforcing correct performance; and (c) record keeping to allow management of individual and collective performance trends, improvements, and deficiencies requiring additional training.

The definition implies a computer-based system (either integral or adjunct to the tactical system) which, when activated, interrupts or overlays the system's normal operational mode to enter a training and assessment mode. Volume 2 of this series, ET as a System Alternative (Strasel et al., 1988), outlined seven attributes of a fully functioning ET system:

1. generates operational input signals appropriate to the system (e.g., target or threat data);
2. feeds these data into and through the operational equipment to the system's operators or maintainers by means of normal display indicators;
3. presents the input data to depict realistically what would occur in a system operational exercise against a real threat. The ET system should also provide the capability to simulate faults and errors to allow training in degraded modes of operation;
4. reinforces performance of normal operator or maintainer tasks and duties in response to simulated mission inputs;
5. assesses and records the performance of operator or maintainer and responds to performance consistent with actual threat actions; provides realistic and continuous feedback on performance accuracy and appropriateness;
6. provides appropriate performance measurement and recording to permit both individual feedback after a session and over time; and
7. usually allows for the presentation of computer-assisted instruction on related job-relevant tasks in addition to operational mission performance tasks (e.g., equipment setup or maintenance tasks).

Fully functioning and integrated ET could be incorporated into most computer-based systems, such as the currently developing command, control, communications and intelligence (C³I) systems; sensor systems; and many weapons systems which rely on computers for integral parts of the tactical system.

APPENDIX B
LIST OF ACRONYMS

AI	Artificial Intelligence
AMC-HQ	US Army Materiel Command-Headquarters
CAI	Computer-Aided Instruction
CBT	Computer-Based Training
CD	Combat Developer
COFT	Conduct of Fire Trainer
CRT	Cathrode Ray Tube
DA	Department of the Army
EIDS	Electronic Information Delivery System
ET	Embedded Training
ETR	Embedded Training Requirements
ICAI	Intelligent Computer-Aided Instruction
I/O	Input and Output
IR&D	Independent Research and Development
MD	Materiel Developer
PEO	Program Executive Officer
PM	Program, Project or Product Manager
PM TRADE	Project Manager for <u>Training Devices</u>
RPV	Remotely Piloted Vehicle
SD	System Developer
SSI	Soldier-System Interface
TD	Training Developer
TRADOC	US Army <u>Training and Doctrine Command</u>